Nuclear Data Adjustment with Whisper for Criticality Safety Applications

Michael E. Rising, *Jennifer L. Alwin, Alexander R. Clark, Robbie MacQuigg, and Bobbi Riedel*

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Nuclear Criticality Safety

- Nuclear data adjustment supports both criticality safety and reactor analysis/design.
- In criticality safety, adjustment has the potential to eliminate conservatism in analysis, but it is dependent on the existence of a large collection of benchmarks that exercise the related data.
  - An example of the effect of the benchmark collection in a specific criticality safety application analysis is shown in the upcoming slides.

Acknowledgements

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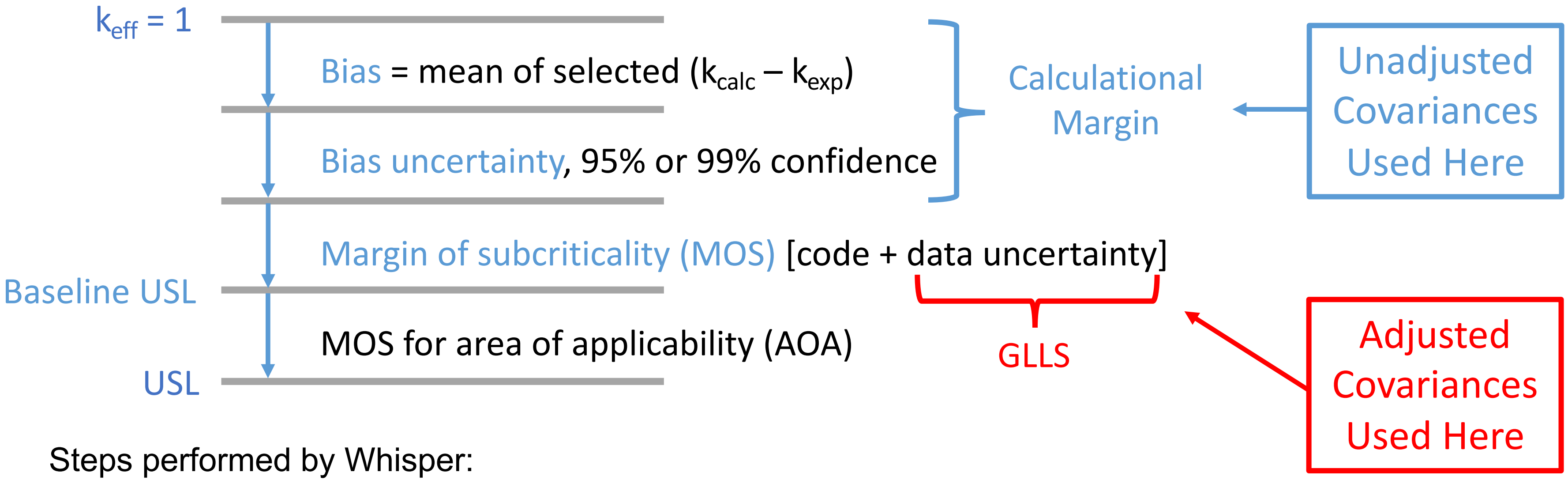
What is Whisper?

- Statistical analysis code using sensitivity/uncertainty-based methods to determine baseline upper subcritical limit (**USL**) for nuclear criticality safety

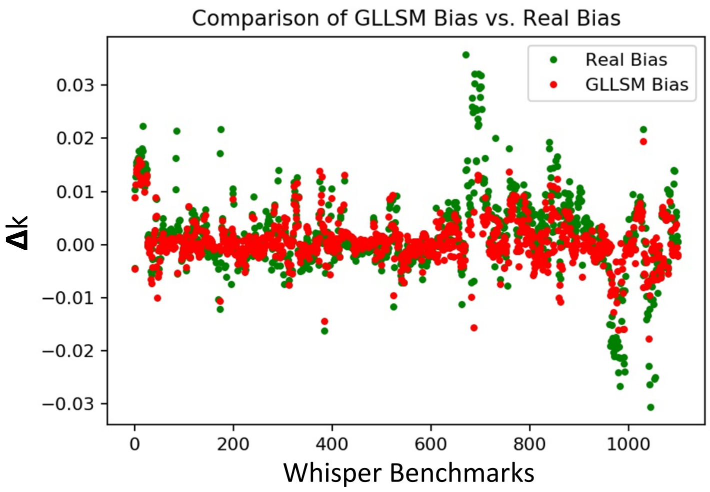


Steps performed by Whisper:

1. Benchmark selection
2. Compute bias and bias uncertainty
3. **Estimate additional margin of subcriticality**

Whisper Use of Nuclear Data Adjustment

- Step 3 includes computing margin of subcriticality due to nuclear data.
- Using GLLS, we adjust the nuclear data to the entire collection of benchmarks and use the **adjusted nuclear data covariance** to estimate residual uncertainties from nuclear data.



- *Real Bias* is the difference between simulation and experiment
- *GLLSM Bias* is the difference between the prior and posterior simulation
- The difference in these could be considered the ***residual uncertainty***

Figure generated by P. Grechanuk when studying the use of Machine Learning methods to predict simulation bias (see DOI: [10.1080/23324309.2019.1585877](10.1080/23324309.2019.1585877))

Example Use of Nuclear Data Adjustment in Whisper

Application **similar** to benchmark suite

- Bare plutonium application

Whisper Outputs	Value (pcm)
Bias	**690**
Bias Uncertainty	**693**
ND Uncertainty (Prior) MOS	1,375
ND Uncertainty (Posterior) MOS	**59**
ND Uncertainty Reduction w/ GLLS	~95%

^{239}Pu Accounts for 94% of Prior Unc.

^{239}Pu Posterior Unc. ↓ ~95%

Application **dissimilar** to benchmark suite

- Plutonium reflected by tantalum

Whisper Outputs	Value (pcm)
Bias	**877**
Bias Uncertainty	**911**
ND Uncertainty (Prior) MOS	3,133
ND Uncertainty (Posterior) MOS	**1,454**
ND Uncertainty Reduction w/ GLLS	~53%

^{239}Pu Accounts for 33% of Prior Unc.

^{181}Ta Accounts for 67% of Prior Unc.

^{239}Pu Posterior Unc. ↓ ~95%

^{181}Ta Posterior Unc. ↓ ~48%

Bold Values Used by Whisper for USL Calculation

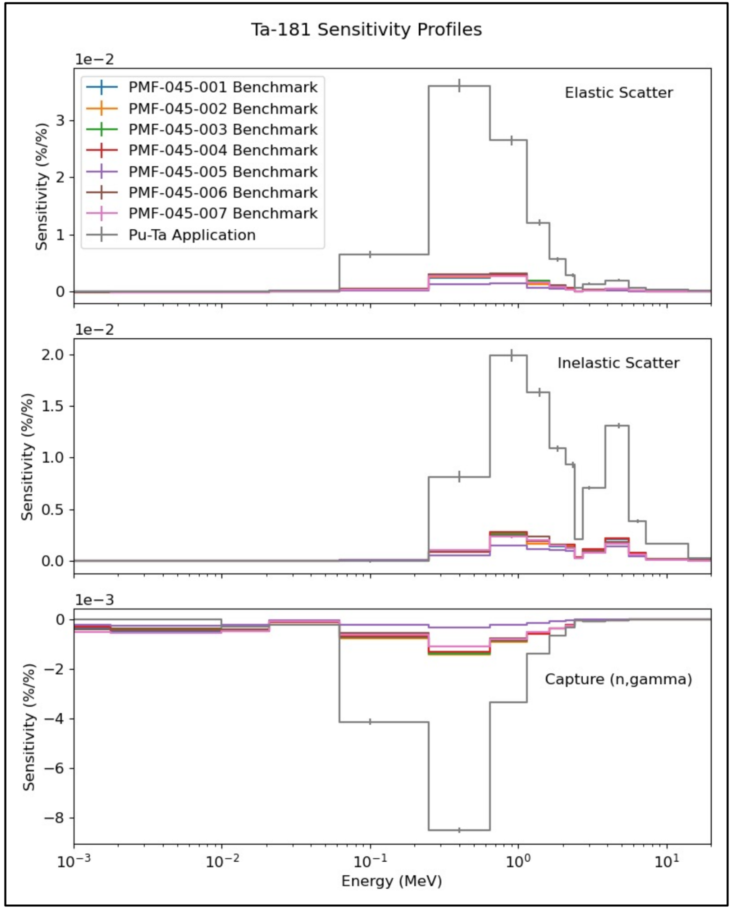
Takeaways from Bare Pu vs. Ta-reflected Pu Examples

- Compared to the hundreds of benchmarks with ^{239}Pu, only 7 benchmarks in the Whisper library contain ^{181}Ta (all within PMF-045 series)

- Therefore, ^{181}Ta adjusted cross section uncertainties are not constrained like the ^{239}Pu adjusted cross section uncertainties because:

  1) So few (and similar) benchmarks used within the context of GLLS,

  2) The sensitivities of the application differ from those of the benchmarks



Conclusions

- Nuclear data adjustment is used by Whisper to compute residual nuclear data uncertainties within a full suite of benchmarks
  - Requires a *complete* set of nuclear data covariances, benchmarks and k-effective sensitivity profiles (for both benchmarks and applications)
- For applications that are **similar** to the full benchmark suite, the residual uncertainties add a small margin to the overall USL calculation
- For applications that are **dissimilar** to the full benchmark suite, the residual uncertainties add a reasonable margin to the overall USL calculation (more conservative)
- This methodology helps to overcome any issues in the released covariance libraries where nuclear data uncertainties appear to be too large

Questions?

Contact: mrising@lanl.gov

Example Use of Nuclear Data Adjustment in Whisper

Application **similar** to benchmark suite

- Bare plutonium application

ND Source of Uncertainty	Prior (pcm)	Posterior (pcm)
^{239}Pu, $\bar{\nu}$	1,229	372
^{239}Pu (inelastic)	824	372
^{239}Pu (elastic)	479	284
^{239}Pu (n,f)	351	338
^{239}Pu, χ	299	99
^{239}Pu (n,γ)	73	70

Application **dissimilar** to benchmark suite

- Plutonium reflected by tantalum

ND Source of Uncertainty	Prior (pcm)	Posterior (pcm)
^{239}Pu ($\bar{\nu}$)	1,245	370
^{239}Pu (inelastic)	574	242
^{239}Pu (elastic)	257	148
^{239}Pu (n,f)	351	337
^{239}Pu (χ)	230	76
^{239}Pu (n,γ)	100	94
^{181}Ta (inelastic)	2,680	1,548
^{181}Ta (elastic)	841	818
^{181}Ta (n,γ)	261	259